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Résumé de l'article

Les aspects économiques de la lutte au doryphore de la pomme de terre, *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) sur la pomme de terre (*Solanum tuberosum*) à l'aide de diverses stratégies ont été étudiés à quatre localités de l'île du Prince-Édouard en 1989. Trois traitements ont été essayés à chaque endroit: 1) une parcelle-témoin non traitée; 2) l'application du *Bacillus thuringiensis* var. *tenebrionis* ou de roténone après l'atteinte d'un seuil de 0,5 équivalent de doryphore de la pomme de terre (EDPT) par tige (1 EDPT = 1 adulte du printemps, 8 larves de premier ou second stade, 3 larves de troisième ou quatrième stade ou 1,6 adultes de l'été) ; 3) l'application d'insecticides selon le programme régulier de pulvérisation des producteurs. À une des localités, le rendement en tubercules des parcelles gérées avec le seuil de 0,5 EDPT par tige a été similaire à celui obtenu des parcelles pour lesquelles le producteur maintenait son programme régulier de pulvérisation, mais trois applications d'insecticides en moins ont été utilisées dans le premier cas. Aux autres localités pour lesquelles la densité de doryphores de la pomme de terre n'a pas excédé le seuil de traitement, le rendement en tubercules a été similaire à celui des autres parcelles des producteurs. Ces résultats indiquent qu'il y a eu des applications superflues d'insecticides par les producteurs.

Comparison of three management schemes for Colorado potato beetle on early-season potatoes in Prince Edward Island

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The economics of managing the Colorado potato beetle, *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) on potatoes (*Solanum tuberosum*) with different strategies was tested at four sites on Prince Edward Island in 1989. Three treatments were tested at each site: 1) an untreated check, 2) an application of *Bacillus thuringiensis* var. *tenebrionis* or rotenone after a threshold of 0.5 Colorado Potato Beetle Equivalents (CPBE) per stalk was reached (1 CPBE = 1 spring adult, 8 first- or second- instar larvae, 3 third- or fourth- instar larvae, or 1.6 summer adults), and 3) applications of insecticide according to the grower's normal spray schedule. At one site, tuber yield of plots managed with the 0.5 CPBE-per-stalk threshold was similar to that of plots where the grower maintained his normal spray schedule, but three fewer applications of insecticides were needed in the former. At the remaining sites, where the density of Colorado potato beetles did not exceed the threshold, tuber yield was similar to that of the grower's plots. This suggests that there were needless applications of insecticides by the growers.

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Introduction

Each year approximately 26 000 ha of potatoes, *Solanum tuberosum* L., are grown on Prince Edward Island, Canada. The principal insects attacking this crop are the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae), the potato flea beetle, *Epitrix cucumeris* (Harr.) (Coleoptera: Chrysomelidae), and the potato aphid, *Macrosiphum euphorbiae* (Thos.) (Homoptera: Aphididae). A preliminary study on Prince Edward Island has shown that uncontrolled damage caused by the Colorado potato beetle reduced yield of 'Russet Burbank' potatoes by 29 % (Stewart and Thompson 1988a). The larvae and adults of the Colorado potato beetle cause indirect losses by defoliating the plants and reducing tuber growth (Cranshaw and Radcliffe 1980; Ferro *et al.* 1983; Hare 1980; Martel *et al.* 1986).

Traditionally, pesticides have been applied according to a regular spray schedule regardless of the presence or absence of pests. This practice can lead to unnecessary applications of pesticides, an increased rate of development of pesticide resistance, and a needless cost to the grower.

Integrated pest management programs for insects of potatoes have been implemented in the western United States (Flint 1986) and in Massachusetts (Hollingsworth *et al.* 1986) but at this point no such program has been adopted in Canada (Holliday and Parry 1987). Wright *et al.* (1987) have implemented an integrated pest management program

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in New York, based on an action threshold which weighs different growth stages of the Colorado potato beetle in relation to defoliation and yield loss. A preliminary study on Prince Edward Island has shown that high yields of potatoes can be obtained by employing a similar threshold (Stewart and Thompson 1988b).

The objective of this study was to calculate the economics of managing a potato crop with regular application of insecticides, no insecticides, and with an action threshold at four sites on Prince Edward Island.

Materials and methods

Four sites of 'Superior' potatoes were located in commercial fields across Prince Edward Island. Crops other than potatoes were grown in all fields in 1988. Fields were planted on 22 May 1989 at Elmsdale (Prince County) and North Winsloe (Queens County), 5 June 1989 at Cornwall (Queens County), and on 6 June 1989 at Summerside (Prince County).

Each site consisted of about 20 rows spaced 0.9 m apart with each row measuring 91 m in length and was divided into three treatments: 1) an untreated check; 2) an application of *Bacillus thuringiensis* var. *tenebrionis* (Trident) at 39.6×10^9 *Tenebrionis* units (TU)/ha or rotenone (Rotenone, 1 % Dust) at 0.4 kg a.i./ha after a threshold of 0.5 Colorado Potato Beetle Equivalents (CPBE) per stalk was reached; and 3) regular applications of insecticides by the grower according to his normal spray schedule.

The threshold of 0.5 CPBE per stalk was adapted from that of Wright *et al.* (1987). They applied insecticides for control of the Colorado potato beetle when there were at least 25 overwintered adults, 40 summer adults, 200 small larvae (first or second instars), or 75 large larvae (third or fourth instars) on 50 stalks. Based on the above-noted estimates, one CPBE per stalk was equated to 1 overwintered adult, 1.6 summer adults, 8 small larvae, or 3 large larvae.

Sites were located at the edge of growers' fields. Each site measured at least 0.17 ha and was divided equally into three treatments. Each measured at least 18.3 m wide (20 rows) by 30.5 m in length. Four border rows (3.6 m) on each side of the site and at least 10 m at the headlands were used to reduce the risk of contamination from pesticide drift and to eliminate edge effects. All plots were managed with cultivation, and applications of fungicides and herbicides as required. The effect of herbicides and fungicides on the Colorado potato beetle was not tested, but weeds and disease were kept at a minimum at all sites.

Sites were monitored on a weekly basis from emergence to senescence. The number of spring adults, first and second instars, third and fourth instars and summer adults of Colorado potato beetles were counted on 30 plants randomly selected per treatment. Each growth stage was divided by its appropriate weight, summed, then divided by the total number of stalks sampled to determine the number of CPBE per stalk. The average number of stalks per plant for 'Superior' was about 4.5. If the 0.5 CPBE-per-stalk threshold was reached, insecticides were applied using a CO_2-pressurized precision sprayer equipped with two disc-core hollow-cone nozzles per row. Since *Bacillus thuringiensis* var. *tenebrionis* is only effective against the larval stages of the Colorado potato beetle (Cantwell and Cantelo 1981), rotenone was applied when the adult population surpassed the 0.5 CPBE-per-stalk threshold. All plots were sprayed with pirimicarb (Pirimor, 50 WP) as required to control aphids. The toxicity of pirimicarb is selective to aphids (McEwen and Stevenson 1979).

Prior to harvest, subsamples were taken from four randomly-selected 7.6-m sections of row in each treatment at each site. Tubers were graded as total and marketable. Marketable potatoes had a diameter of at least 4.0 cm. An analysis of variance was performed using GENSTAT (Payne *et al.* 1987) and the least significant differences were calculated using a level of significance of 0.05.

The economics of managing the crop using action thresholds compared with regular or no applications of insecticides were determined using the methodology described by Stewart and Sears (1988). The costs and revenues associated with the use of action thresholds involved the employment of one scout visiting each field once a week during the growing season. This cost was estimated at \$20.00/ha (J. Diamond, personal communication, 1990) and is based on the cost charged by the Provincial Department of Agriculture for scouting potatoes in Prince Edward Island.

Prices of the various insecticides used in this study were quoted as follows: fenvalerate (Belmark) \$112.50/L, carbaryl (Sevin, 50 WP) \$8.25/kg, carbofuran (Furadan, 480F) \$25.65/L, methidathion (Supracide) \$12.48/L (Agro Co-op, A. Livingston, personal communication, 1989), cypermethrin (Cymbush) \$81.00/L (Phillips Feed Service Ltd., P. Malone, personal communication, 1989), rotenone (Rotenone, 1 % Dust) \$3.65/kg (Island Seed Co. Ltd., D. Deacon, personal communication, 1989), and *Bacillus thuringiensis* var. *tenebrionis* (Trident) \$5.00/L (Sandoz Agro Canada Ltd., F. Buchanan, personal communication, 1989).

Applications of synthetic insecticides by the grower were assumed to be at the highest rates suggested by the Advisory Committee on Potatoes (Anonymous 1988). Custom applicators in southern Ontario charge \$13.54/ha for a ground application of a pesticide (Fisher 1988) and this was the cost used in our study.

The price quoted by the P.E.I. Potato Marketing Commission (G.J. Fougere, personal communications, 1989) for tablestock 'Superior' potatoes sold to Ontario-Québec markets was \$149.02/t.

Results and discussion

North Winsloe was the only site where populations of Colorado potato beetles exceeded the 0.5 CPBE-per-stalk threshold. Treatments at the other three sites therefore consisted of a check/threshold (average of the check and threshold plots) and grower's treatment.

The weekly counts of CPBE per stalk in the check plot at the North Winsloe site surpassed the action threshold on 18 July (Fig. 1) and remained above the threshold for 2

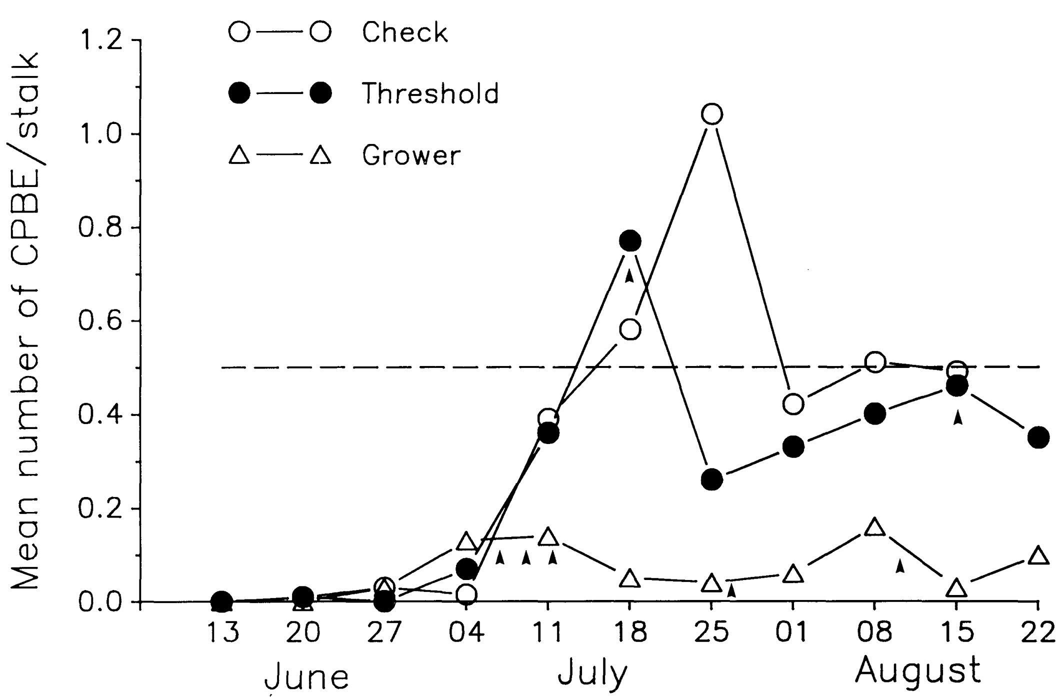

Figure 1. Density of Colorado Potato Beetle Equivalents (CPBE) per stalk in plots under three management systems at North Winsloe, Prince Edward Island, 1989. — threshold of 0.5 CPBE/stalk; (▲) application of insecticide.

weeks before declining on 1 August, possibly due to the pupation of larvae or dispersal of insects from the plot. When the counts of CPBE per stalk surpassed the action threshold in the threshold plot on 18 July (Fig. 1), *Bacillus thuringiensis* var. *tenebrionis* was applied. The action threshold was approached again on 15 August and rotenone was applied to control adults. The counts of CPBE per stalk in the grower's plot remained low throughout the growing season and never surpassed 0.16 CPBE per stalk (Fig. 1). The grower applied four sprays of *Bacillus thuringiensis* var. *tenebrionis* at a rate of approximately 33.0 TU/ha and one dusting of rotenone at a rate of 0.4 kg a.i./ha. There was no significant difference ($P > 0.05$) in either total or marketable yields between the threshold and grower's plots (Table 1). Total yield ($P \leq 0.05$) and marketable yield ($P \leq 0.10$) of the threshold and grower's plots were higher than the check plot.

The weekly counts of CPBE per stalk in the check plot at the Elmsdale site peaked at 0.303 on 25 July (Fig. 2A). The counts of CPBE per stalk in the grower's plot were kept low by one spray of methidathion applied on 15 June, and one spray of fenvalerate applied on 17 July 1989. Both total and marketable yields were greater ($P \leq 0.05$) in the check plot than the grower's plot (Table 1) even though more Colorado potato beetles were found in the former (Fig. 2A). Other studies have also shown that greater yields can be obtained when plants are damaged. Harris (1974) suggested that removal of apical dominance in many plants by low levels of insect injury can result in increased branching and ultimately an increased yield. Cranshaw and Radcliffe (1980) noticed that the development of auxiliary shoots following defoliation of potatoes by insects resulted in higher yields.

The counts of CPBE per stalk at the Cornwall and Summerside sites remained well below the 0.5 CPBE-per-stalk threshold throughout the season (Figs. 2B, 2C). Cypermethrin and carbofuran were applied to the grower's plot at the Cornwall site, while carbaryl was applied to the grower's plot at the Summerside site. There was no significant difference ($P > 0.05$) in total or marketable yields between the check and grower's treatments at either site (Table 1).

The adoption of a crop scouting program based on action thresholds showed in this particular study that insecticide usage could be reduced. Even though three fewer applications of insecticides were used, yield of tubers from plots managed with the 0.5 CPBE-per-stalk threshold at the North

Table 1. Yield of 'Superior' potatoes under three management systems at four sites on Prince Edward Island, 1989

Site	Treatment	Number of sprays	Yield (t/ha)§	
			Total	Marketable
Winsloe	Check	0	18.8a	8.0a
	Threshold†	2	23.6b	11.7a
	Grower†	5	21.9b	11.8a
Elmsdale	Check/Threshold	0	35.3a	28.9a
	Grower‡	2	31.8b	25.6b
Cornwall	Check/Threshold	0	31.8a	24.5a
	Grower¶	2	29.8a	22.8a
Summerside	Check/Threshold	0	27.2a	14.3a
	Grower∞	1	25.7a	14.6a

§ Numbers in a column within each location followed by the same letter are not different ($P > 0.05$) using the LSD test.

† Threshold: One application of *Bacillus thuringiensis* var. *tenebrionis* on 18 July and one application of rotenone on 15 August 1989. Grower: Applications of *Bacillus thuringiensis* var. *tenebrionis* on 7, 10, 13 and 26 July and one application of rotenone on 11 August 1989.

‡ One application of methidathion about 15 June and one application of fenvalerate about 17 July 1989.

¶ One application of cypermethrin about 12 July and one application of carbofuran on 7 August 1989.

∞ One application of carbaryl about 27 July 1989.

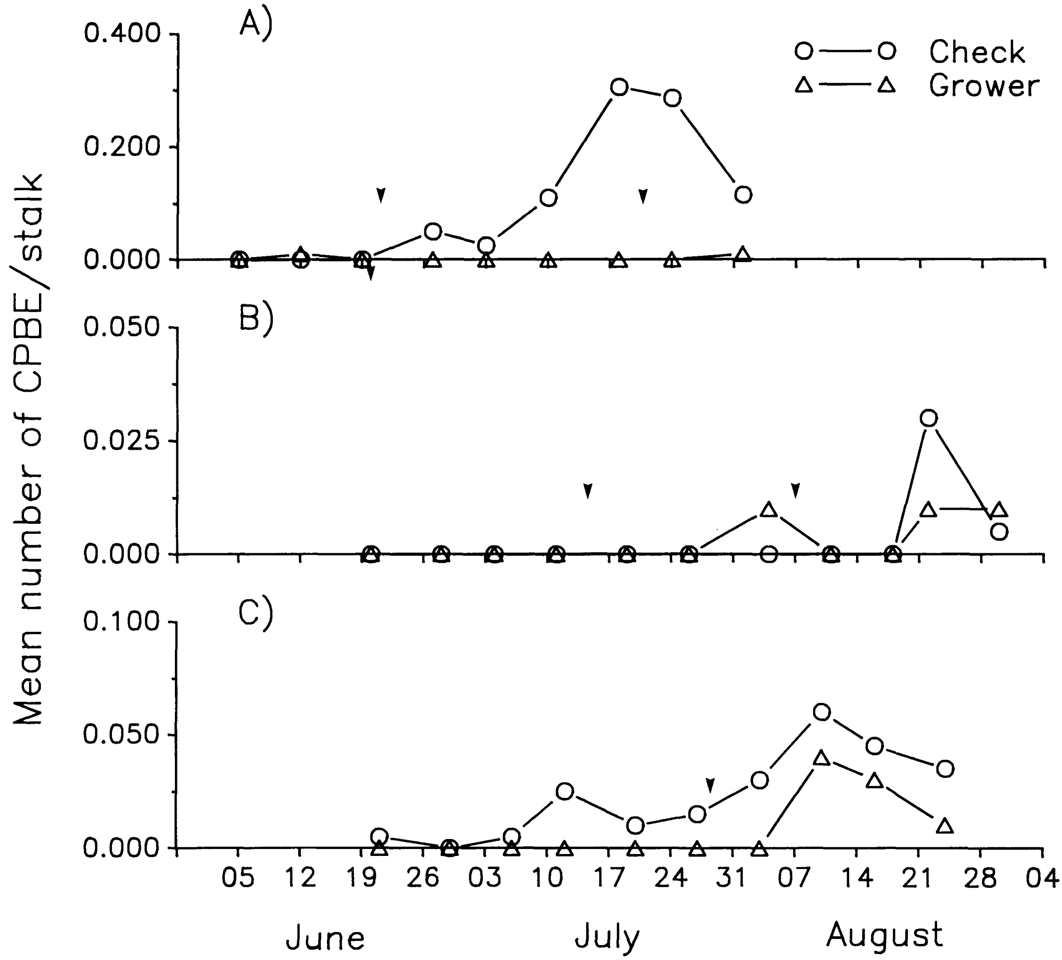

Figure 2. Density of Colorado Potato Beetle Equivalents (CPBE) per stalk in plots under two management systems in 1989 at: **A**) Elmsdale; **B**) Cornwall; and **C**) Summerside. (▼) application of insecticide.

Winsloe site was similar to the yield from plots managed by the grower. At the three sites where the Colorado potato beetle populations did not reach the action threshold (Summerside, Elmsdale, and Cornwall), yield of the check was never lower than that of the grower's plot. All of these sites, therefore, received unnecessary applications of insecticides by the producers.

The calculations of costs and revenues associated with the three management systems tested are shown in Tables 2 and 3. Differences in marketable yield between the check and grower's treatments at the Cornwall and Summerside sites and the threshold and grower's treatments at the North Winsloe site were not statistically different ($P > 0.05$) and were therefore averaged for the calculation of crop value. At the North Winsloe site, the highest total revenue was obtained by managing the crop according to the action threshold. The revenue in the threshold plot was \$160.62/ha higher than for the grower's plot and \$311.71/ha greater than for the check plot (Table 2).

Compared with the strategy employed by the growers, managing the crop with the threshold increased net revenue by \$563.44/ha at Elmsdale, \$58.63/ha at Cornwall, and \$11.69/ha at Summerside (Table 3). At each site, net revenue for plots managed with no insecticides and with no monitoring costs (i.e. the check) would be \$20/ha greater than that of the threshold

Table 2. Cost and revenues associated with the three management systems for potatoes at North Winsloe, Prince Edward Island, 1989

Economic components	Check	Threshold	Grower
Insecticide costs ($/ha)	0	233.08	413.70
Scouting costs ($/ha)	0	20.00	0
Pest control costs ($/ha)§	0	253.08	413.70
Marketable yield (t/ha)†	8.01	11.8	11.8
Crop value ($/ha)‡	1193.65	1758.44	1758.44
Revenue ($/ha) ¶	1193.65	1505.36	1344.74

§ Insecticide costs + scouting costs.

† Yield of potatoes measuring at least 4.0 cm in diameter (n=4).

‡ Marketable yield × $ 149.02/t.

¶ Crop value − Pest control costs.

Table 3. Costs and revenues associated with two management systems for potatoes at Elmsdale, Cornwall, and Summerside, Prince Edward Island, 1989

	Elmsdale		Cornwall		Summerside	
Economic components	Threshold	Grower	Threshold	Grower	Threshold	Grower
Insecticide costs ($/ha)§	0	91.67	0	78.63	0	31.69
Scouting costs ($/ha)	20.00	0	20.00	0	20.00	0
Pest control costs ($/ha)	20.00	91.67	20.00	78.63	20.00	31.69
Marketable yield (t/ha)†	28.9	25.6	23.7	23.7	14.5	14.5
Crop value ($/ha)‡	4306.68	3814.91	3531.77	3531.77	2160.79	2160.79
Revenue ($/ha) ¶	4286.68	3723.24	3511.77	3453.14	2140.79	2129.10

§ Insecticide costs + scouting costs.

† Yield of potatoes measuring at least 4.0 cm in diameter (n=14).

‡ Marketable yield × $149.02/t.

¶ Crop value − Pest control costs.

plots. Using the former strategy is not recommended because growers would lose access to information on other insect pests, diseases, and the overall health of the crop. In addition, a grower could suffer a significant yield loss if populations of the Colorado potato beetle surpassed the threshold.

Conclusions

The cost to the grower of employing a scout is at least partially offset by savings in insecticide applications. Use of the action threshold at the four sites studied resulted in higher net revenue than managing the crop with applications of insecticides independent of population levels of the Colorado potato beetle. The cost of crop scouting and the adoption of the 0.5 CPBE-per-stalk threshold may not always result in increased revenue, but the cost of production may be reduced by only applying insecticides as needed. An added benefit would be a reduction of pesticides in the environment.

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